LEVEL II

MSAG-1 REPORT 001

MEASUREMENT SYSTEMS ADVISORY GROUP

FINAL REPORT

APRIL 1974

Prepared For

LONG RANGE ACOUSTIC PROPAGATION PROJECT

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Prepared For

LONG RANGE ACOUSTIC PROPAGATION PROJECT

(10) John H. /Cawley
Roy L. /Father
Scott C. /Daubin
Sidney /Kulek
James M. /Snodgrass

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412235

April 23, 1974

Dr. Roy D. Gaul
Manager, Long Range Acoustic Propagation Project
Office of Naval Research
Code 102-OSC
Department of the Navy
Washington, D. C. 22217

Dear Dr. Gaul:

In accordance with the instructions contained in your memorandum of 23 October 1973 we have investigated various aspects of measurement systems employed in oceanographic exercises sponsored by your office and have prepared the enclosed "Report of the Measurement Systems Advisory Group" which is forwarded herewith. Copies of this report have been distributed only to you, the committee members and adjunct members. No further distribution is contemplated unless you so direct.

Having completed this assignment the group considers itself dissolved.

Sincerely yours,

John H. Cawley

John H. Cawley

Roy L Rather

Roy L. Rather

Scott C. Daubin

Scott C. Daubin

James M. Snodgrass

James M. Snodgrass

Sidney Kulek

Sidney Kulek

102-OSC:RDG:bsj
7 May 1974

Dr. S. C. Daubin
Rosenstiel School of Marine and
Atmospheric Sciences
University of Miami
10 Rickenbacker Causeway
Miami, Florida 33149

Mr. S. Kulek
Xonics, Inc.
6837 Hayvenhurst Avenue
Van Nuys, California 91406

Dear Scott and Sid:

The final report dated 23 April 1974 from the Measurement Systems Advisory Group has been reviewed and is accepted with great pleasure. The report presents the first complete examination of ocean acoustic measurement systems used in the majority of LRAPP sponsored exercises. I find the analyses relevant and the recommendations cogent. The efforts by you and your associates are outstanding in every respect and very much appreciated.

The report will be distributed to selected members of the user community for their information and comment. Because of the potential requirement for further deliberations, I prefer that MSAG not be formally disbanded at this time.

Sincerely,

R. D. GAUL
Manager, LRAPP

Copy to:
J. H. Cawley, ADL
E. H. Mitchell, BKD
J. P. Nardello, HCI
R. L. Rather, CEC
J. M. Snodgrass, SIO

ACKNOWLEDGEMENT

MSAG wishes to acknowledge the significant contributions of the Manager LRAPP, his staff and other members of the LRAPP community. The guidance to MSAG provided by Dr. Gaul, on several occasions, prevented the pursuit of interesting diversions. The continued attention of Mr. Ronaldi, of the LRAPP staff, provided information relative to LRAPP goals, immediate plans and constraints.

Presentations by Texas Instruments, Inc., Woods Hole Oceanographic Institution, Naval Underwater Systems Center, Naval Research Laboratory and Environ Electronics, Inc. relative to past operations, problem areas and suggested improvements provided a data base from which MSAG worked. In addition, the efforts of Woods Hole in conducting strumming tests were crucial in finding a course of action to solve the strumming problem.

Many individuals at various activities contributed greatly to the effort. Space precludes individual acknowledgement to each; however, two persons deserve special note: R. Swenson of NUSC and Paul Boutin of WHOI.

Finally MSAG gives special thanks to the excellent technical support provided by Mr. Nardello of Hydrospace Challenger, Inc. and Mr. Mitchell of B-K Dynamics, Inc.

FOREWORD

After seven months of investigation and deliberations the Final Report of the Measurement Systems Advisory Group (MSAG) was delivered to the Manager, Long Range Acoustics Propagation Project (LRAPP) in April 1974. In early May 1974, the Manager, LRAPP sent the report for critical review to the following representative sample of the technical community involved in the LRAPP type of acoustics measurement processes:

Applied Research Laboratory
University of Texas at Austin

Marine Physical Laboratory
Scripps Institution of Oceanography

Naval Research Laboratory
Washington

Naval Undersea Center
New London Laboratory

Naval Underwater Systems Center
New London Laboratory

PME-124
Naval Material Command

Texas Instruments, Inc.
Dallas

Westinghouse Research and Development Center
Pittsburgh

Woods Hole Oceanographic Institution
Woods Hole

REACTIONS OF THE TECHNICAL COMMUNITY

In all, six replies were received. The distribution of comment for both the general thrust of the major problem areas covered in the report and for specific recommendations thereunder is presented in Table I. The following definitions will assist in interpretation:

- PRO - - - - - - - In favor of the recommendation as stated.
- PRO-BUT - - - - In favor of the recommendation, but with some small changes.
- CON - - - - - - - Against the recommendation as stated for whatever reason
- CON-QVA - - - - Against the recommendation because of a question of the validity of the premises or data on which the conclusions were based.
- NOC - - - - - - - No comment.
- ALT - - - - - - - Alternative recommendation set forth by the reviewer.

TABLE I. SUMMARY OF MSAG REPORT COMMENTS

MSAG RECOMMENDATION	RESPONSE: FOR		AGAINST		OTHER	
	PRO	PRO-BUT	CON	CON-QVA	NOC	ALT
A. Capsule Processing & Recording			2	1	2	1
A1. Analog/Digital System	1		1	2	2	
A2. Separate Software Development			1		5	
A3. Repackaging of RPM			2	1	2	1
B. Connectors	2			1	2	1
B1. LRAPP Define Performance Requirements	1				5	
B2. Provide Alternate Sources of Connectors	1		1		4	
B3. Standard Connector Test Procedures and Records	1		1	1	3	
B4. Personnel Training in Connector Care	1				4	1
B5. Connector Materials Investigations	1				5	
B6. Transparent Materials	1				5	
C. Cables	2		2		2	
C1. Cable Handling & Maintenance Improvement Program	1			1	4	
C2. Don't Standardize on Synthetic Yet; Evaluate End FY 75	2			1	3	
C3. Use, But Don't Replenish, Armored Cable	1			1	4	
C4. Fair All Cables	2				4	
C5. Use Standard Cable Lengths	2		2		2	
D. Strumming Counter Measures	1			2	3	
D1. FSW Testing at WHOI				1	5	
D2. FSW Procurement			2		4	
D3. Hair-in-Braid for WHOI KEVLAR	1				5	
D4. Post FY 75 Exercise Evaluation					6	
E. End-to-End Calibration	2	1			2	1
E1. Electronic Insertion	1				4	1
E2. Hyd. Impedance Series Insertion	1				5	
E3. IPV Control for Synchronization	1				5	
E4. 0.1 dB Accuracy					6	
E5. -35 dB Cross Talk Limit					6	
E6. At Least Two Frequencies					6	
E7. 0.1 Hz Frequency Stability					6	
F. Analog Magnetic Tape & Recording/Reproduction	2	1			2	1
F1. Use of Verified Tapes					6	
F2. Investigate Alternatives to 3M 801	1				5	
F3. Record/Reproduce Heads Design & Care				1	5	
F4. Use of Alignment Tapes		1			5	
F5. Use of Test Tapes					6	
F6. Central Tape Management	1				4	1
G. Hydrophone Calibration	2	1			3	
G1. Uniform Calibration Procedure		2			4	
H. Administrative Recommendations	2			1	3	
H1. 10% of Budget for Development	2				4	
H2. LRAPP Developments Under LRAPP Control				1	5	

The comments of each reviewer opposite each recommendation were placed in one of the six categories above which best fit. It is noted that:

- No respondent supported all recommendations;
- No respondent opposed all recommendations;
- The majority of the responses on specific recommendations fell within the "no comment" category;
- More support was received for the general thrust of the recommendations under the problem areas than for the specific recommendations.

RESPONSE TO COMMENTS

A subcommittee of the original MSAG[1] was appointed by the Manager, LRAPP to consider the comments and respond thereto through this foreword. Practically all comments were perceived to be constructive in intent. Many of the criticisms of the report were well taken and are concurred with on subsequent consideration by the subcommittee. Others were rejected by the subcommittee either on the basis of fact or judgement. Certain comments transmitted the impression that the reviewer had not read the report carefully or did not understand certain aspects of the system on which they were advising. Specific rejoinders to comments are indicated below:

a. The discussion and recommendations under "Strumming Countermeasures", Sects. 2.4.3. and 2.4.4, should not have dealt exclusively with FSW. The pre-occupation with FSW was a result of the deadline demand for a fairing for existing cables for application during the summer of 1974. At the time of the report the MSAG was unaware of available alternatives. The important and significant developments of Swenson of NUSC in this field, in particular the Prodesco wrap-on fairing for application to an existing unfaired cable, should have been noted and recommended for consideration for subsequent evaluation.

b. The absence of support for the analog/digital <u>in-situ</u> recording system was apparently based largely on concerns for feasibility in terms of power or computing capacity. There was little discussion as to the issue of experimental need such as the requirements for extremely narrowband processing or the expansion of dynamic range for SUS.

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1 The subcommittee consists of Mr. Sidney Kulek of XONICS Inc. and Dr. Scott C. Daubin of the University of Miami.

c. It is agreed that the proposed reconfiguration of the RPM is too heavy. Only two reviewers noted the need for reconfiguration and offered suggestions.

d. It is true that concern for ACODAC problems pre-empted the report to the neglect of other automatic recording acoustical systems. This focus reflects the fact that of all the systems ACODAC is the only one fully under LRAPP development control.

SUBSEQUENT DEVELOPMENTS

In the interim since the issuance of the report an entire operational year has transpired. Many events of this period were directly influenced by the report, or certainly bear consideration in light of the recommendations of the report. Among these events are the following:

a. LRAPP has contracted for centralized tape management with Martin-Marietta Corp., Denver, Colorado. This organization provided successful centralized services, tape verification, duplication and archiving for the WESTLANT 74 exercise.

b. LRAPP has contracted for uniform hydrophone calibration services with Hydrospace-Challenger, Inc. The calibrations conducted at the NRL Underwater Sound Reference Division, Orlando, Florida have been efficiently managed.

c. FSW fairing material was acquired and used on both compliant and armored arrays. No evidence of strumming has been observed in the acoustical records. The recommended formal evaluation between fairing types has not been conducted.

d. A new generation of ACODACs, under development at Texas Instruments, will use a digital central control unit. Fourteen track tape recorders will be retro-fit into existing ACODACs.

OBJECTIVES OF MEASUREMENT SYSTEMS DEVELOPMENT

One comment stated that the MSAG report did not well define the mission of the group or the objectives of the report. On review, the subcommittee concurs that the statements of mission and objective could be clarified. Accordingly for emphasis they are restated as follows:

MSAG's mission is to consider the measurement requirements for area acoustic assessment against the existing capabilities and to advise the Manager, LRAPP as to how to proceed to rectify deficiencies in order that LRAPP may better fulfill its mission.

The measurement process is a key to the continued progress of development in ASW. Measurement systems need to be considered against the measurement requirements in the light of the following properties:

a. Capability - What variables can be measured? What parameters can be derived from the measurement?

b. Efficiency - What data acquisition rate can be achieved at what cost? What data processing rate can be achieved at what cost?

c. Quality - What accuracy and precision do the data possess?

d. Reliability - What are the probabilities of successful data acquisition and processing for the required time intervals and under the given operating conditions?

It is the concern of all involved in the measurement systems development process to improve performance to the required degree in each of these systematic areas.

The overall objective of the MSAG report is to assist in this undertaking. Time will tell as to whether the objective was achieved.

Sidney Kulek

Sidney Kulek

Scott C. Daubin

Scott C. Daubin

25 April 1975

Date

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EXECUTIVE SUMMARY

The Measurement Systems Advisory Group (MSAG) which was formed by the Manager, LRAPP, to advise him on technical and administrative matters regarding the improvement and application of measurement systems used in LRAPP exercises, submits its findings herewith. The group met eight times at various laboratories, plants and institutions which are integral participants in the LRAPP effort. MSAG reviewed the Acoustic Data Capsule (ACODAC) program at Texas Instruments, Inc., the Woods Hole Oceanographic Institution and the University of Miami, the Moored Acoustic Buoy System (MABS) and components development programs at the New London Laboratories of the Naval Underwater Systems Center, and the Ambient Noise Buoy (ANB) program at the Naval Research Laboratory. In addition the group or its individual members discussed specific problems with developers or manufacturers at various times and places during the investigation.

Following the instructions of the Manager, LRAPP, recommendations were categorized by the time required for their implementation. There were three categories: near term (for FY 75 exercises), mid term (3-5 years) and long term. Ultra-short term recommendations were delivered to personnel of Texas Instruments, Inc. working on the LRAPP effort there; these were primarily measures to improve the performance of the tape recorder.

MSAG has organized its near term recommendations into six separate categories centered on the ACODAC system: these include cables and connectors, strumming countermeasures, end-to-end calibration, management of analog magnetic tape and tape recording reproduction, uniform hydrophone calibration, and ACODAC system error analysis. All of these recommendations are directed towards improvement of the quality of the data recovered by the ACODAC or similar systems. In many of these recommendations the point stressed was the requirement for unified management procedures which need to be instituted and guided by the LRAPP office.

The one mid term technical problem addressed concerned the in-situ data processing and recording system. The recommendation outlines a parallel/digital ACODAC system which utilizes all of the major components currently employed in the analog system but adds a programmable digital processor in parallel. The analog/digital ACODAC would overcome two of the major problems currently limiting performance: dynamic range constraints which make simultaneous propagation loss and ambient noise measurement difficult and the long and expensive time constant for post exercise processing.

MSAG recommends that LRAPP support a continued effort to improve acoustic measurement systems which are under its own administrative control. Some significant fraction of the annual budget, up to 10% in the opinion of MSAG, should be allocated for this purpose.

1.0 INTRODUCTION

For the success of its operations at sea the Long Range Acoustic Propagation Project (LRAPP) is critically dependent on the proper functioning of complex measurement systems. One of these, the Acoustic Data Capsule (ACODAC), has been developed completely under LRAPP funding; others such as the Moored Acoustic Buoy System (MABS) have received support from LRAPP as well as other sponsors. Still others, VIBROSEIS for example, were developed by other agencies or by industry and sometimes for purposes quite different than acoustic area assessment. But in all cases LRAPP maintains a justifiably keen interest in the reliability, efficiency and performance of any system used as part of a LRAPP exercise.

It is important to note that for the purposes of MSAG consideration the term "measurement system" was construed in its broadest context; it includes all of the hardware and software required to generate signals in the ocean, sense, measure and record them in situ and to process and analyze them ashore.

In the course of the first several exercises, EASTLANT, IOMED, CHURCH GABBRO, SQUARE DEAL and CHURCH ANCHOR, considerable experience was gained from the exposure of these systems to the rigors of the ocean. Some components failed outright; others have proved to be very reliable and efficient. Some have not failed, but rather have shown a progressive deterioration with use over time. Others neither failed nor deteriorated, but proved inefficient.

An acoustic area assessment exercise is an expensive undertaking. It is therefore imperative that the lessons of experience be studied and applied where possible. With this purpose in mind Dr. Roy Gaul, manager of LRAPP, on 2 October 1973, asked several individuals* each of whom had experience in the systems aspect of LRAPP field exercises to constitute an ad hoc advisory group to investigate the general matter of the systems employed in LRAPP exercises, their reliability, their efficiency, their cost, the associated operational procedures, and to advise him on measures to raise the overall level of effectiveness. After all those asked agreed to serve, the verbal request was followed by a memorandum dated 23 October 1973 in which Dr. Gaul announced the formation of "an informal Measurement Systems Advisory Group - - - - - - - to assist in assessing the performance and potential improvements of the several measurement systems generally used in LRAPP sponsored oceanographic exercises".

The MSAG met at the following locations and dates for the purpose indicated:

Location	Date(s)	Purpose or Organization
San Diego, CA	15 October 1973	At NUC; briefing by Dr. Roy Gaul on overall LRAPP problems
Dallas, TX	25 October 1973	At Texas Instruments, Inc.; ACODAC technical review
Woods Hole, MA	15 November 1973	At WHOI, ACODAC technical review

* The persons asked to become members of the group include Mr. John H Cawley, Dr. Scott C. Daubin, Mr. Sidney Kulek, Mr. Roy L. Rather, and Mr. James M. Snodgrass. Messrs. Eugene H. Mitchell and John P. Nardello were asked to serve as adjunct members for the purpose of providing expertise and service in certain specialized areas. Mr. Thomas C. Ronaldi served as the LRAPP liaison.

Location	Date(s)	Purpose or Organization
New London, CT	16 November 1973	At NUSC, MABS and component technical review
Washington, DC	27 November 1973	At NRL, ANB technical review
Miami, FL	14-15 December 1973	At University of Miami, compliant array and connector technical review, organization of technical subject areas and assignment of responsibilities
Miami, FL	5-6 February 1974	At University of Miami, review of recommendations, report assignments
Rockville, MD	21-22 March 1974	At Hydrospace-Challenger, Inc., compilation of report

In addition, several MSAG members went to sea in MEDITERRANEAN SEAL and witnessed VIBROSEIS operations in early January 1974.

The meeting on 25 October 1973 at Dallas, Texas was mostly devoted to ultra-short range problems since the contractor, Texas Instruments, was in the process of preparing hardware for an exercise (MSS test), although some longer range problems were considered. The problems as the advice rendered are outlined below:

A. GeoTech Model 17373 tape recorders were apparently running slow after the capsule temperature equilibrated with the surroundings. Woods Hole had not experienced this problem. MSAG recommended that the driving gear train be checked for dirt, proper lubrication and proper alignment. It was later determined that the problem lay in the main drive motor and gear box; when these components were replaced the problem disappeared.

B. Closely associated with the specific sympton expressed in "A" above is the entire matter of the maintenance of cleanliness around the capsule, tapes and tape recorders, electrical connectors and other sensitive equipment. MSAG specifically recommended that on board NORTH SEAL, the ACODAC van be maintained as a clean area, or a reasonable approximation of a clean area in view of the difficult conditions aboard ship.

C. The main power supply had become a source of difficulty. In any deployment, particularly so in a multiple deployment, it is essential that the main battery be fully charged and that the ambient pressurizing oil bath be free of any salt water contamination. To assure these points in the RPM as presently designed was time consuming and difficult. But to ensure a fully charged battery required reading specific gravity and this required access to the cell tops. In spite of the difficulties MSAG recommended that the main battery of each ACODAC deployed be inspected prior to the MSS test. This was a short range solution to a long range problem. In approaching the longer range solution MSAG suggested a redesign of the RPM to make the battery more accessible.

At a meeting in Washington, D. C. on 27 November 1973, the manager of LRAPP issued verbal guidance, the essence of which is summarized below:

A. Past performance, cost, etc., is only useful as a guide toward MSAG recommendations. Documentation of history for LRAPP is not beneficial.

B. Recommendations for hardware should be provided in three categories:

(1) Near Term - Those immediate fixes required to get ready for early FY 75 exercises.

(2) Mid Term - Given the measurement system technology and inventory available to LRAPP, a recommendation is desired re the advisability of consolidation or homogenization of the three independent development programs into a mature measurement system for continued usage for the next 3 to 5 years. Such a recommendation should include the use of proven new technology not available to the original developments.

(3) Long Term - Recommendation(s) are solicited in this category for expansion of measurement system capability: e.g., array length and number of phones, beamforming, horizontal deployment, etc.

C. Procedural recommendations are solicited re quality control measures (both pre exercise testing; e.g., pressure testing of array cable; and check off sequences to assure adequate performance of hardware operated by lower skilled personnel). Standardization of equipment parameters (e.g., step size, equalization, etc.) is part of this quality control consideration.

In the matter of the mid term and long term problems enumerated by the LRAPP Manager, MSAG has responded by the recommendation which appears in paragraph 2.2 below on a digital in situ recording system which would be capable or processing a much larger set of hydrophones than the six currently employed. MSAG noted that the New London Laboratory of NUSC was in the development process of a horizontal array for MABS II and that it was likely to be employed in a LRAPP exercise during FY 1975. Evaluation of this device after its FY 1975 employment should indicate a direction to proceed for future long term developments.

On 15 December 1973, the group issued to the Manager of LRAPP a general format letter explaining the methods by which recommendations would be transmitted to the Manager of LRAPP. On the same date recommendation number one which concerned the development of a parallel digital/analog ACODAC in-situ signal processing system was transmitted. The issuance of those letters which constitute recommendations by piecemeal increment was intended to take advantage of all available lead time for system improvement in anticipation of the fiscal 1975 field operations. Subsequent events showed that insufficient funds were available to the LRAPP office to respond affirmatively in a timely manner. Therefore, these two letters can be considered canceled and superseded by this document. The digital/analog recommendation has been slightly revised and is again presented in the report below.

2.0 TECHNICAL PROBLEMS AND RECOMMENDATIONS

2.1 GENERAL.

Among the many technical problems investigated by the group, seven have been identified as being of exceptional importance to the success of the LRAPP mission. These problems are listed below and discussed in the paragraphs to follow:

A. In-situ processing and recording
B. Cables and connectors
C. Strumming countermeasures
D. End-to-end calibration
E. Analog tape and tape recording/reproduction
F. Hydrophone calibration
G. System error analysis

Of these technical problem areas only "A" is in the mid term category as defined by the Manager LRAPP; the remainder, "B" through "G" fall within the definitions of short term problems.

2.2 IN SITU PROCESSING AND RECORDING SYSTEM.

2.2.1 LIMITATIONS OF PRESENT SYSTEM. The present ACODAC analog signal processing and recording system, when used interchangeably to measure ambient noise and signals from explosive sources or CW projectors, has a number of limitations which are outlined and discussed below:

A. Insufficient Dynamic Range

The most severe limitation is the insufficient dynamic range for both ambient noise and shot transient measurement. In any given gain state the overall dynamic range, which is limited by the analog tape recorder, is about 33 dB. On the other hand, the dynamic range of the hydrophones is about 80 dB. By overlapping gain states an effective system dynamic range of about 60 dB is achieved, but the minimum residence time in any gain state is one minute. Since short range shots often rise 60 dB above ambient, if the system were measuring ambient at the time of arrival of such a shot signal, an overload condition would ensue. The analog system accommodates shots as well as ambient by a method of stepwise gain changes; this procedure is either wasteful in SUS charges in that it requires a "setting" charge prior to each "measured" charge; otherwise it ignores ambient by maintaining itself in too insensitive a gain state. The existing method requires a predetermination of the level of the gain state into which the system will transform itself on arrival of the setting shot; the choice of this state is not a trivial problem and it can lead to either the loss of information or complete system saturation on all shots.

B. Data Reduction Time and Cost

The present system requires that the analog tape be processed after recovery. Normally three types of processing are accomplished: 1/3 octave ambient acoustic energy processing, or shot signal processing. Each of these requires a playback run through some form of digital computer. The normal (7-1/2 ips) time required is 3-1/2 hours per channel; for six channels of data in each of the above three forms a tape would require up to 63 hours for the initial, unedited reduction and double that (or 126 hours) to produce a complete set of edited processed data. This, of course, is time and dollar consuming. Another problem associated with analog reduction processing is the overall system fidelity, or linearity and retention of calibration. To preserve hard won data the original analog tape is often duplicated prior to processing and the duplicate tape is used in the reduction process. Due to many problems, such as head alignment, this duplicating process, unless very painstakingly (and expensively) controlled, can produce serious errors in the derived levels.

C. Frequency Stability

The stability of the present system is adequate for 1/3 octave measurements. For CW measurements of SOFAR refracted energy decreasing the resolution bandwidth will improve signal to noise until the width of the central line exceeds the processing resolution. It has been shown that a resolution of 0.1 Hz contains the energy of the central line, but not that of the surface modulation sidebands.* However, a signal to noise is not the only factor; temporal coherence is another important aspect of the CW signal which determines the maximum usable detection integration time. Experiments with fixed systems indicate that the width of the CW line is about 0.004 Hz and that this width is due to the interaction of the acoustic field and a temporally and spatially variable sound velocity structure.**

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* See for example, G. E. Ellis letter of 5 March 1974 to R. D. Gaul on subject, "High Resolution CW Processing".

** H. A. DeFerrari and K. Yacoub, "The Effects of Horizontally Varying Internal Wave Fields on Multipath Interference for Propagation Through the Deep Sound Channel", 86th Meeting of Acoustical Society of America, paper No. HH10, Los Angeles, California, October 30 - November 2, 1973.

Future experiments for temporal and spatial coherence of moving sources will require spectral resolution of the order of 0.01 Hz. Thus we seek to improve the current resolution by a factor of ten. Whether this is possible or not with the available hardware remains to be demonstrated. Certainly a first step is to place a suitably high and stable reference frequency on each data channel. Tests should then be conducted to determine the attainable resolution.

2.2.2 ADVANTAGES OF ANALOG SYSTEM. Recording data in analog form has a number of advantages. One of these is the high information density achievable in analog recording. For example, compare a digital system which is equivalent in bandwidth and dynamic range to the present 6 data channel analog system which has an upper limit of 300 Hz, a 33 dB dynamic range and a tape speed of 15/160 ips. An equivalent digital system would require a minimum sampling rate of 600 6-bit measurements per second per channel, or 3600 bytes per second. To use the same quantity of tape as the analog system, the digital system would require a tape recording density of 38,400 bytes per inch. This is about 20 times the density of the current state of the art. Thus any currently feasible digital processing scheme must discard information which is recorded by the present analog system. In a digital system one must choose a priori what is going to be measured and what is going to be discarded. If the wrong choice is made, if subsequent events show that additional measurements were required, the missing information cannot be resurrected from the condensed data. Retention of the analog system would preserve subsequent processing options as well as redundancy in event of failure in the digital system.

2.2.3 ADVANTAGES OF AN IN SITU DIGITAL SYSTEM. The following points summarize the advantages of a programmable in-situ processing system:

A. Immediate Availability of Processed Data

There has been a long standing requirement for the availability of processed data immediately on recovery of the instrument, or shortly thereafter. The present data reduction system is both time consuming and costly as discussed in paragraph 2.2.1B above. The digital system would process the data in real time in-situ. Reading, plotting and listing the tape would be all the post-recovery processing necessary in order to make use of the data.

B. Efficient Shot Processing

The digital system can have a dynamic range to match that of the hydrophones. In recording shot transients there would be no requirement for gain state switching; thus the signal acquisition reliability would increase and the absence of the requirement for a setting charge would decrease the cost of operations.

C. Adaptability and Operational Flexibility

The programmable digital system would provide adaptability and operational flexibility through its software. For example in the recording of ambient noise, the number of processed bands, N_b, times the number of hydrophones, N_h, divided by the recording interval, T_s, provides a processing throughput rate limit, $N_b N_h / T_s$. As long as this number is not exceeded, there is complete flexibility to alter the variables. For example, a system capable of handling 15 bands for each of 6 hydrophones could easily be changed to handle only 6 bands, but for 15 hydrophones. In a similar fashion the capacity of the system could be programmed to be divided between ambient noise and CW processing, or to alternate measurements of CW and ambient. Also, the digital system provides the possibility of interchannel processing, such as correlation. The processing program used would depend on the experimental objectives; through this flexibility the utility of the instrument would be multiplied.

2.2.4 CHARACTERISTICS OF PROPOSED SYSTEM. It is recommended that a programmable digital processing system be incorporated in the ACODAC signal handling circuitry in parallel with the existing analog system and that it record on the existing analog tape recorder using the band above 300 Hz. The heart of the digital processing system could be a small, programmable digital computer. A block diagram of the proposed scheme is shown in Figure 1. The key specification requirements of the parallel digital system are outlined below:

A. The system will compute and record one minute averages or ambient noise in each of 15 bands (14 one-third octave bands plus 1 broadband) as is now accomplished in ACODAC data processing ashore. Dynamic range will be 60 dB; this will require 13 x 15 = 195 bits each minute for each data channel at 98 percent undistorted power output.

B. The system will automatically recognize shot transients and compute and record energy in up to 15 bands as well as the arrival time of the signal.

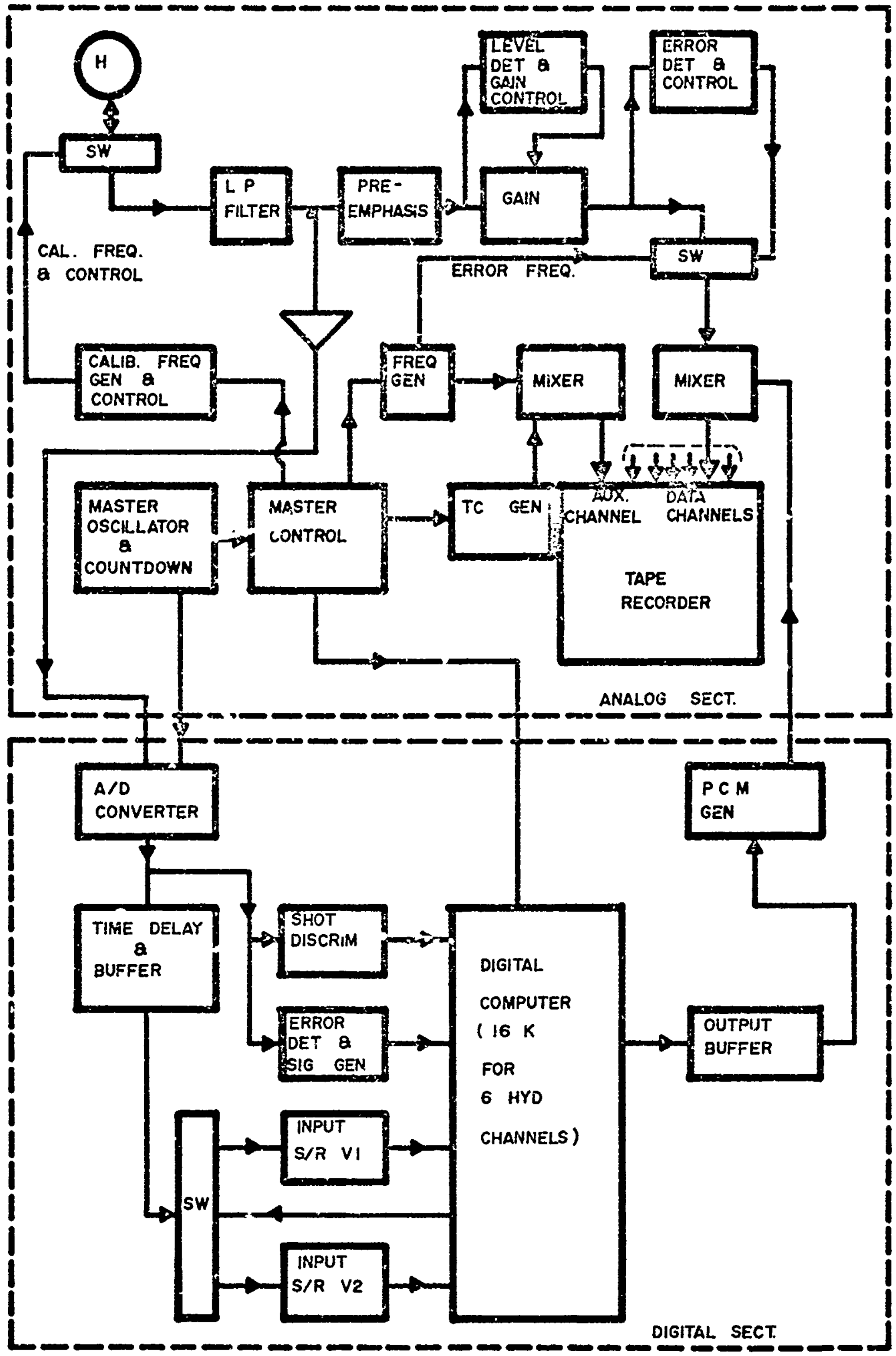

Figure 1. ACODAC Signal Processing System

C. The system will provide for complex demodulation and recording of CW signals with resolution limited by available integration time.

D. The system will retain the analog information on the tape in the band below 300 Hz.

2.2.5 FEASIBILITY. We have made preliminary feasibility analyses and so far have found no technical problem whose solution requires new technology; in fact in many technical areas, such as LSI and micro-power modules, the field is just entering the range of feasibility and as time progresses the situation promises to improve. The concept which follows is based upon only rough estimates of the digital processing requirement; detailed designs which relate hardware characteristics to data requirements, such as filter bandwidth and skirt shapes, remains to be done in the design phase. Three problem areas concern information coding and the size and power demand of the proposed mini-computer which would be the heart of the digital system.

A. The digital data are to be logged on to the analog tape in the band between 300 and 400 Hz. Among the many possible coding schemes we have considered a PCM system with a 3 Hz basic repetition rate, riding on a 350 Hz carrier. These coding pulses would be placed simultaneously on each of the six data channels. Pulse durations of 85 ms (30 cycles) and 170 ms (60 cycles) for binary zero and one respectively were used in the analysis. Thus in each minute there would be available 180 bit spaces which would be divided into 15 words using only 165 bit spaces. The question of spectral interference of these pulses into the data band below 300 Hz was investigated; it was found that the power spectrum of the pulse is down by about 24 dB at a frequency separation of 50 Hz from the carrier.

B. The Teledyne Series TDY 52 computer is an example of a compact computer which would be applicable in terms of space and power requirements. It is discussed here only as one example to substantiate feasibility, not as a design choice among competitors. The basic module is a disc less than 3 inches in diameter with 2,048 words of 16-bit memory. Configured as a 16-bit mini-computer with 4,096 words of memory the power requirements are less than 7 watts. Assuming that four of these mini-computers would be required in order to provide the 16K memory estimated to be required for a single ACODAC, a total additional power requirement of 28 watts is foreseen. Exclusive of converters, coders and I/O devices the space requirements for the mini-computer are estimated to be about the same as that of a portable typewriter; there is adequate available space in the ACODAC IPV to accommodate this system.

C. Assuming storage batteries of 95 AH at 12 volts were used to generate a continuous 30 watts of energy for the 10 2/3 day continuous operation, 7 batteries would be required for an estimated additional weight of about 789 pounds which could be compensated for by adding buoyancy to the RPM.

2.2.6 REPACKAGING. The increased battery weight would require repackaging of the RPM. A suggested repackaging arrangement is shown in Figure 2. This arrangement is compact and protects the IPV. The elimination of glass balls increases reliability by removing the implosion hazard with its possible consequences of damage or loss of buoyancy. Using 38 lbs/cu ft syntactic foam which is currently

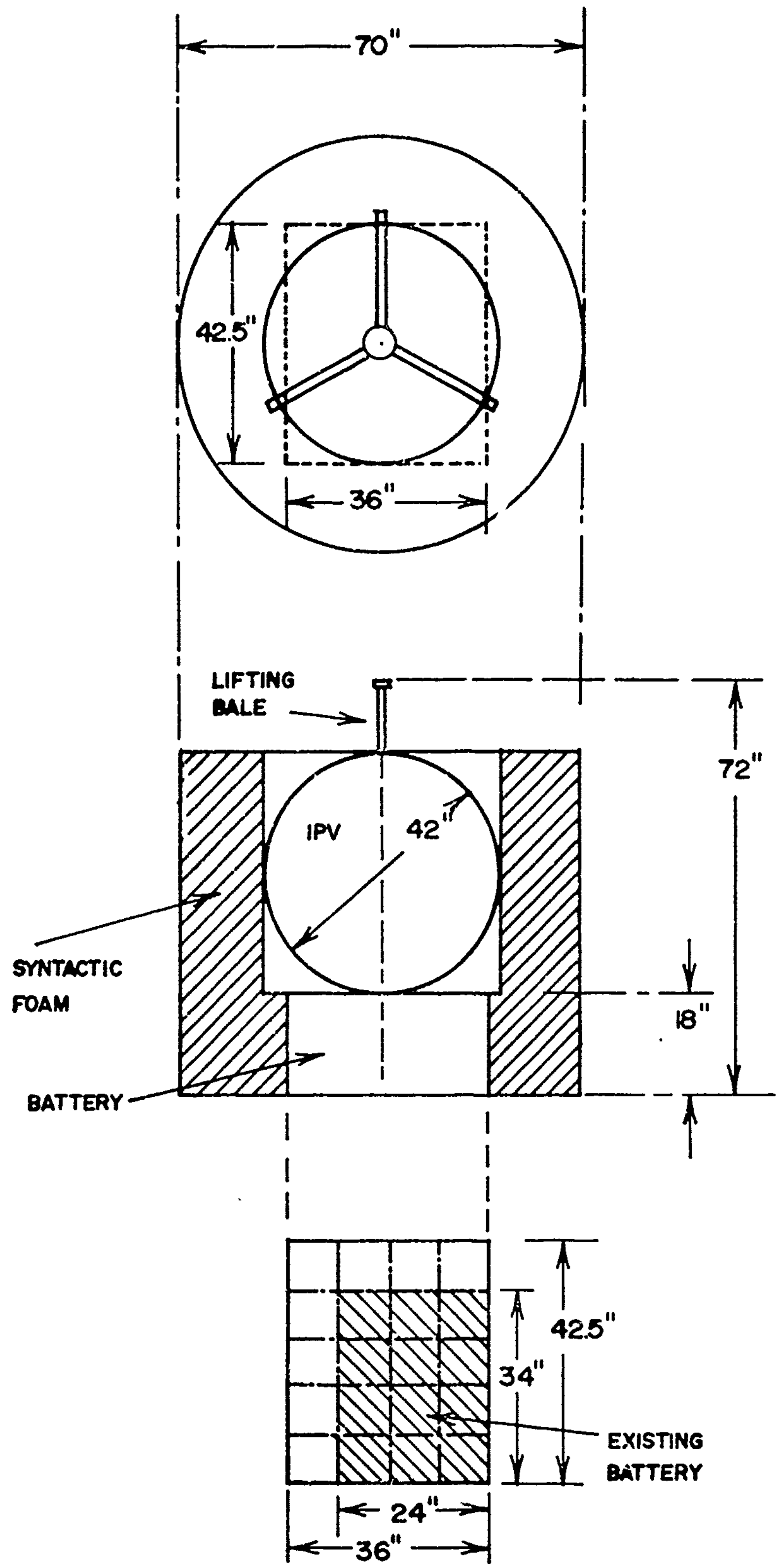

Figure 2. RPM Syntactic Repackaging Scheme

available rated at 10,000 psi operating pressure the following weight and buoyancy characteristics are obtained:

	Air Weight	Buoyancy
IPV	1400 lbs	700 lbs
Battery	1389 lbs	-1166 lbs
Syntactic Foam	1906 lbs	1304 lbs
Handling Gear	40 lbs	-38 lbs
TOTAL	4735 lbs	800 lbs

2.2.7 COST AND DEVELOPMENT TIME. Due to time constraints we have not conducted a detailed cost analysis for implementation of the digital concept; however, based on the experience of various members of the group it is estimated that the hardware costs, exclusive of prototype engineering and development, for each ACODAC would lie in the vicinity of \$30,000. Minimum total costs for the first prototype, including engineering, would be about \$260,000. At this level of support hardware development should not exceed 18 months; concurrent software development should require about six months. If development time were an important factor, it is estimated that at a total cost of about \$500,000, the first prototype could be produced in one year.

2.2.8 IMPLEMENTATION. Should this concept be implemented by the LRAPP office it is recommended that it be carried out in a three step program. The first step should be the preparation of a performance specification and cost estimate based on a preliminary design in which various tradeoff decisions are made. Step two would be the actual hardware development and step three would be the software development, concurrent with the last half of step two. It is recommended that separate organizations be tasked for each step.

2.3 CABLES AND CONNECTORS

2.3.1 THE PROBLEM. Cables and connectors, both electrical and mechanical, constitute a major portion of the acoustic measurement systems now in use; they are considered together because of their intimate physical relationship. The experience of over thirty ACODAC deployments has generated a wealth of performance information on the steel armored electromechanical cables and to a lesser extent on the compliant cable. In assessing and evaluating this information MSAG noted the lack of uniform record keeping through which problems could be better defined and solutions found. The cable and connector problem divides naturally into two parts: one, design and fabrication and two, handling and maintenance. The number of successful deployments attests to the adequacy of the basic design and fabrication processes in electromechanical cables; this conclusion is reaffirmed when one considers the general abuse to which most cables and connectors have been put. The questions would then arise as to why there should be any effort at basic design improvement. The answer lies in economics and efficiency. The steel wire cables are difficult to handle, degradable by salt water and expensive to provide with anti-strumming fairing. Alternate designs will be discussed below. It is in the area of handling and maintenance that the greatest shortcomings are found and the greatest opportunities for improvement lie.

2.3.2 HANDLING AND MAINTENANCE. The electrical cables and connectors presently in use in the ACODAC, MABS, and ANB systems are different in concept and design but are exposed to common operational and maintenance difficulties. Typical examples include:

- Dirt and other foreign material on the electrical connector pins and mating surfaces.

- Dirty O-rings and O-ring grooves.

- Nicks on O-rings and mating surfaces.
- Tensile loads placed on electrical connectors.
- Attempts made to reuse bird caged cables.
- Cables crushed by trucks when laid out in a parking lot or pier while being cut to length during cable make-up periods.
- No adequate washdown of cables with fresh water after recovery of cables and instruments.
- Cables and connector sets untested for continuity and electrical leakage immediately after recovery.

These common examples of cable-connector problems and lack of adequate maintenance and testing can lead to noisy and intermittent operation and premature system failure.

The manner in which the connectors, hardware, cables, and lubricants are handled during their useful life at sea and ashore is the single most important factor that determines their overall reliability and performance; this needs LRAPP guidance and support. It is important then for the Manager to exert strong influence on all contractors to:

a. Extend provisions for the education and training of personnel in the proper care, lubrication, and handling of connectors, cables, mechanical hardware, and buoyancy packages throughout their useful life span;

b. Require complete and carefully logged, connector and cable test, and quality control records in accordance with good engineering and business practice;

c. Conduct field failure analysis programs to investigate, analyze and help eliminate the causes of cable and connector problems; and

d. Insure that the conclusions reached and the lessons learned be circulated among LRAPP contractors to help them improve systems performance.

Incorporation of these measures into each of the major LRAPP acoustic measurement programs will ensure the degree of cable and connector reliability and future performance that is consistent with the present state-of-the-art.

2.3.3 ELECTROMECHANICAL CABLE TYPES AND USE. Several types of mooring cables, connectors, termination hardware, and buoyancy packages are in use in ACODAC, MABS II, and ANB hydrophone systems.

- Armored multi-conductor cable (ACODAC)
- RD-58U Coaxial cable (ANB)
- Compliant polypropylene cable (ACODAC)
- Fiber-B high strength synthetic cable

a. The U.S. Steel Amergraph 7H37-SB, 3/8-inch diameter, seven conductor cable, with moulded polyurethane connectors developed by Environ Electronics, has proven reliable and has been used successfully throughout the ACODAC program. However, it has a high specific gravity, is stiff and difficult to handle, degradable by salt water, and, as normally used in high tenstion, is highly susceptible to strumming in the low frequency bands of interest.

b. The Naval Research Laboratory has utilized RG-58/U coaxial cables with Mecca connectors in its ANB system. Since the coax cable and connectors are inexpensive they are discarded after each deployment and new cables of the proper length are then made up for the next deployment. This tends to avoid major handling and storage difficulties and NRL reports no failure or degradation in system performance has been traced to cables and connectors in ANB deployments.

c. The compliant polypropylene mooring cable was developed at the University of Miami primarily for acoustic measurements with simultaneous current profiling. This cable is 3/4-inch in diameter and was designed for hi-drag applications. It contains up to 10 No. 22 AWG conductors with insulation thickness twice that used in the 7H37-SB Amergraph; these conductors are used in pairs for each hydrophone, thus reducing common mode cross talk. Early analysis of hydrophone data indicates the compliant low-tension mooring line shows promise in this application.

d. Fiber-B is a unique synthetic fiber of very high tensile strength, high strength to weight ratio and high modulus (low stretch). This material has been engineered into a 36-conductor mooring line over the past two years by the New London Laboratory of the Naval Underwater Systems Center. Recently Fiber-B, under the trade name KEVLAR, has been made into a parallel stranded cable by Wall Industries Inc., Beverly, New Jersey. This material is very promising, however there is little experience on exposure to the real ocean environment.

2.3.4 STANDARDIZED CABLE LENGTHS. The deployment of buoys at sea is a complicated procedure and delays due to faulty or damaged cables and connectors are time consuming and costly and must be avoided. Consequently, MSAG recommends that experiments be designed for standardized and pre-tested lengths of ACODAC cables with attached connectors and that these standard length cables be used in future LRAPP deployments. Standard lengths of cable with standard connector configurations will simplify cable makeup, inventory and use at sea. Preliminary consideration by MSAG indicates that standard cables with attached connectors made up, tested, and packaged in 100 and 300 meter lengths would be suitable for most buoy deployments in LRAPP exercises. In addition some longer length cables of the order of 1000 meters in length will also be needed for most deployments.

2.3.5 CABLE RECOMMENDATIONS SUMMARY. Having studied the various aspects of the problem and with the background presented above, MSAG submits the following recommendations regarding electromechanical cables:

a. The LRAPP office should devise, organize, institute and monitor a program to improve the handling and maintenance of electromechanical cables. This should be effected through contractors, but the requirements should be uniform and the record keeping responsibility should be defined specifically. The objective of such a program is both to improve the reliability of existing cables and to derive collated data through which future improvements in design, handling or maintenance might be made. See Section 2.3.2 above.

b. Although synthetic cables offer several apparent advantages over steel armored cable, there is insufficient experience at this time to standardize on a replacement design. It is recommended that further experience be gained with the compliant cable of the University of Miami as well as the KEVLAR cable recently proposed by the Woods Hole Oceanographic Institution. To implement this it is recommended that both compliant and KEVLAR cables be used during the

FY 75 exercises and that their handling be controlled and documented as per "a" above. After the field exercises an evaluation and comparison should be made toward the objective of standardizing in the subsequent years' exercises.

c. The present inventory of steel armored electromechanical cable should be used, but not replenshished.

d. All cables should be faired to prevent strumming.

e. Exercises should be designed to use standard cable lengths where feasible; 100, 300, and 1000 meters are suggested.

2.3.6 <u>UNDERWATER ELECTRICAL CONNECTOR PERFORMANCE AND TEST REQUIREMENTS</u>. Several manufacturers are capable of supplying electrical connectors for ACODAC, MABS, or other acoustic measurement systems to depths of 15,000 feet. In the experience of the ACODAC project one of these has consistently supplied connectors of acceptable quality and price. The key to this quality is the personal attention which a single experienced, competent individual pays to all phases of fabrication. The fabrication, assembly, and test of these connectors is an art, and special care is necessary to ensure the operational reliability required by the LRAPP measurement program. Little documentation is available describing these procedures and important methodology is claimed to be proprietary. Variation in encapsulation materials, improper installation if inserts, and variation in tolerances are examples of problem areas that make uniformity from unit to unit difficult to obtain. At present there is a lack of specifications and documented quality control both in the fabrication and assembly of connectors and in the final testing of these units. As a result, MSAG recommends that the Manager, LRAPP support preparation of a set of performance and test requirements for these high pressure electrical connectors sufficient for LRAPP to developed alternate sources of supply. These requirements should be aimed at improving the uniformity, performance and reliability of the electrical connectors.

2.3.7 CABLE-CONNECTOR TEST REQUIREMENTS. Although there is a lack of adequate confirming statistical data, experience suggests that cable-connector electrical characteristics degrade with use. Since this degradation can cause errors in LRAPP measurements, a unified set of tests and test procedures are required to verify the integrity and performance of cables and connectors prior to and after each deployment. As a minimum, the tests required are low resistance bridge type continuity, and 500-volt megger electrical leakage tests. The continuity and leakage tests should be made between conductors and between each conductor and the armor (where applicable) with both polarities as follows:

a. With the cable and connector system in air.
b. With the completed cable connector system immersed in a salt water hydrostatic test chamber or, with the cable and connectors immersed in a few feet of salt water after an appropriate soaking period of a least 24 hours.

Test procedures that incorporate the tests described above need to be formulated and are required of all new cables and connectors before and after they are deployed in LRAPP exercises. Continuity and minimal leakage values need to be defined and all test results must be logged in an acceptable format such as Figure 3 for each cable-connector configuration so that changing electrical characteristics are clearly tabulated throughout their life span. The log data will serve as a basis for improvement of component specifications as meaningful engineering data are developed.

Sample

Connector-Cable Test Data Form

1. Manufacturer Information. Cable Mfg. _____ Mfg. Date_____

   Connector Mfg. _____ Mfg. Date_____

2. Cable Type _____ Serial No. _____ Length_____

3. Connector Type and Serial No. _____ _____

4. Deployment No. _____ Date In _____ Date Out_____

5. Storage: indoor _____ months; outdoor _____ months

Leakage Test Data in Megohms

500 V Megger Serial No. ____

Positive Megger Lead

Negative Megger Lead

Pin	1	2	3	4	5	6	7	8	9	10	Armor/Ground
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
Armor											

Figure 3. Connector-Cable Test Data Form

2.3.8 POLYURETHANE PERMEABILITY TO SALT WATER. It is reported* that salt water penetration increases with successive deep water deployments. Clearly, this is a materials problem and warrants investigation, but MSAG recommends that these efforts be sponsored elsewhere in the research community. However, the Manager, LRAPP should be aware of this potential problem and should emphasize the need for uniform continuity and leakage tests of cable-connector assemblies as discussed paragraph 2.3.7 above. MSAG believes that the recommended action is adequate for determining the degradation of these components throughout their normal life cycle.

2.3.9 CONNECTOR COVER CAPS AND PLUGS. Dirt and other foreign matter can severely damage connector bodies, ruin their water tight integrity, and make the electrical contacts noisy. Cover caps and plugs must be provided for use with each connector body and connectors must be capped and sealed at all times when not terminated.

2.3.10 CONNECTOR ENCAPSULATION. Connector encapsulation procedures, materials, water tight integrity and bonding to other materials are all part of the connector reliability problem. Air voids within the encapsulated components can cause additional problems particularly at high pressure where volume distortion of the connector can cause severe water leakage problems. Since this kind of situation can often be spotted visually MSAG strongly recommends that only transparent polyurethane compounds be used to encapsulate cable connectors in the future.

* H. Hamburg of Environ Electronics mentioned this problem based on his recent experience but presented no experimental data.

2.3.11 <u>CONNECTOR RECOMMENDATIONS SUMMARY</u>. With respect to electrical connectors separately or in combination with electromechanical cables, MSAG recommends the following procedures and actions:

a. LRAPP should prepare a set of performance requirements for electrical connectors.

b. LRAPP should develop alternate sources of underwater electrical connectors.

c. Uniform electrical test procedures for underwater connectors and cables should be prepared and LRAPP should require that they be followed. These should require testing before and after each major exercise. LRAPP should require that records of these tests be maintained in order to provide a data base from which future procurement and operational decisions can be made. This recommendation is closely associated with item "a" of paragraph 2.3.5 above.

d. LRAPP should require that contractors properly train personnel in the handling and care of electrical connectors. Particular points that need to be stressed are:

(1) Never put a mechanical load on an electrical connector.

(2) Always cover both the male and female section of an electrical connector when not in use. Sufficient caps and plugs must be available for this purpose.

(3) Always lubricate "O" rings and "O" ring grooves properly before assembly of the connector. Insure that pins and sockets are free of lubricant.

(4) Always inspect both sections of a connector for evidence of dirt prior to assembly. Never assemble a dirty connector,

(5) On recovery carefully inspect connectors for evidence of leakage. Log all observations.

e. LRAPP should keep abreast of the state-of-the-art in connector materials. In particular, any evidence of water absorption under pressure into polyurethane should be carefully evaluated as to its electrical consequences in a polyurethane connector. MSAG does not believe that LRAPP should sponsor materials research to resolve problems of this type, but should exert influence to see that others conduct such research and should be alert to use the results of any information thus developed.

f. Since many connector defects are observable if the connector is made from transparent material, it is recommended that this be done where feasible. Polyurethane is normally a semi-transparent material; when used as a connector body polyurethane should not be pigmented.

2.4 STRUMMING COUNTER MEASURES.

2.4.1 THE PROBLEM. Strumming is a phenomenon to be expected whenever a long bare cable is subjected to a fluid flow normal to the axis of the cable. The driving force derives from coherent shedding of vortices by the cable at the Strouhal frequency which is directly proportional to the velocity of flow and inversely proportional to the diameter of the cable. The response of the cable to the driving force is a function of its effective length, its tension, linear mass density and the various items of hardware installed along the line which constitute "point" masses. The response of a cable in seawater is strongly damped by forces which depend on the viscosity of seawater and the dimensions of the cable. The fundamental frequency of transverse vibrations of the cable to a first approximation varies inversely as its "free" span length and directly as the square root of the ratio of tension to linear mass density. In general it can be said that if the fundamental cable response frequency is at or near the Strouhal driving frequency strumming is going to result and its intensity will be greater the closer the system is to resonance. Strumming is a serious measurement system problem because it degrades acoustic data. In a typical ACODAC mooring the strumming frequency will vary anywhere from 1 to 4 Hz and the "signal" will be rich in harmonics, sometimes extending as high as 50 Hz. The acoustic effect from strumming is due to two mechanisms; at this point it is unclear which of the two is dominant. The first mechanism involves the physical shaking of the hydrophone due to cable motion which produces an acceleration response at the output of the transducer. The second mechanism is the actual radiation of acoustic energy by the strumming line, the near field of which is sensed by the hydrophone.

2.4.2 APPROACH TO SOLUTIONS. The above paragraph suggests all of the various countermeasures which are known to be effective against strumming. These may be divided into two main categories described by the phrases, one, "eleminate it" and two, "learn to live with it".

Since the latter measures tend to be less expensive than the former, the LRAPP effort concentrated on these initially. The natural frequency of the cable system is one variable partially under control of the mooring designer. Of the three parameters, length, linear mass density and tension, the one most directly amendable to design variation is tension. The problem is that tension affects the fundamental frequency only through its square root; that is, to reduce the natural frequency by a factor of two it would be necessary to reduce tension by a factor of four. Because of the extremely long arrays involved in most ACODAC moorings, natural frequencies tend to lie considerably below the Strouhal driving frequency, hence reducing the natural frequency even further would be a change in the correct direction to reduce strumming. When compared with the armored cable systems, the compliant array reduced tension from about 1500 to 200 pounds, a ratio of 7.5 which resluts in a reduction in the fundamental response frequency by a factor of 2.7. In general reducing the tension by this amount is not feasible unless special precautions are taken. The compliant cable will not kink and the array design involved the use of multiple slope and azimuth recorders from which the hydrophone depths could be determined. A second countermeasure under the "learn to live with it" category is to desensitize the hydrophone to strumming. This has been done in the basic design of the ITC 8004, 8020, 8020A and 8030 hydrphones through the incorporation of an "acceleration cancelling" feature. Another countermeasure at the hydrophone is to mount it resiliently to the cable; the resilient mounting attenuates vibrations, thus isolating the hydrophone from the motions of the cable. A final strumming countermeasure at the hydrophone is to reduce the low frequency sensitivity of the hydrophone by altering the mechanical design of the hydrophone element and the electrical design of the preamplifier. This countermeasure has the strong disadvantage of reducing sensitivity in a frequency range of considerable operational importance. All of the above countermeasures have been taken with partial success. The performance of the compliant array in recent exercises demonstrated that strumming was much less of a problem than in the armored, high tension arrays.

However, data from these tests demonstrated that these measures were still insufficient. Even though it may involve significant expense it is thus necessary to go to the heart of the problem, that is, to eliminate the strumming at the source. It has long been known that strumming can be cured by either eliminating the vortex shedding or breaking up its coherence. The former is achieved by installing a streamlined fairing over the cable, the latter by destroying the cable symmetry. Successful countermeasures are judged not only on their strumming attenuation effectiveness but by their cost, ease of installation, reliability and general amendability to handling. For cables typically two and one half miles in length, the provision of streamlined fairing would be economically preposterous and furthermore it would be most difficult to handle. Therefore it is necessary to find some other means to reduce the amount or coherence of the vortex shedding. NUSC has routinely provided a ribbon fairing on the acoustically active sections of MABS moorings which has apparently avoided strumming in these parts of the line, thus suggesting the effectiveness of the ribbon fairing as a countermeasure. As part of an investigation to determine the best fairing for ACODAC cables, several types of "spoiler" fairing were tested recently at the Woods Hole Oceanographic Institution under the supervision of an MSAG member. The results of these tests are discussed below.

2.4.3 ACODAC FAIRED CABLE STRUMMING TESTS PERFORMED AT WHOI. WHOI prepared a dual-line mechanical structure for comparative strum testing of lines from the pier at WHOI. One line - a bare cable - was used for reference. The other line of equivalent length was the test line. Several faired cables were tested. All cables were subject to equal tension and to the same water velocity that flowed past the dock. The water depth is in excess of 60 feet and water velocities varied from 0 to 2 knots. Accelerometers were attached to both reference and test cables. Water velocities were measured by Savonius type current meter.

The first system tested was a cable wrapped with wire lacing. It was learned in short time that it passed the antistrumming "feel" test but the hooks that made up the lacing system made the cable application difficult since the hooks became snagged on various items. Certain material deficiencies were also noted with the aluminum wire used in the lacing. For these reasons the tests were concluded and deemed unsatisfactory.

The second system tested was an ACODAC polyurethane ribbon faired cable, the ribbons having been solvent-bonded to the polyurethane sheath outside the armored wire cable. This cable was supplied by NUSC. The ribbons were 2 inches wide and 5 inches long with 2-inch gaps between ribbons. This system remained free of strumming when the reference cable was rather violent. In addition, this cable was easy to handle. Measurements made after accelerometers were attached indicated a 12 times reduction in acceleration violence and consequent noise generation. The cost estimated to be $3.00 per foot is high primarily due to the excessive amount of hand labor required. Due to cost, this otherwise good system was eliminated from further consideration.

The third system tested was Hair-in-Braid type of cable fairing produced by Wall Rope Works of Beverly, New Jersey. A sample run of the fairing is now on order by NUSC for the MABS system and WHOI plans to order a complete ACODAC array of KEVLAR (See Section 2.3.5) with Hair-in-Braid fairing.

Next tested was Fringe Spiral Wrap (FSW) conceptually developed by Roy Rather working with members of the WHOI team. The FSW process is described in detail below. The inventors believe that FSW will significantly reduce strumming. It shows promise for the following reasons: Antistrumming characteristics are expected to be equal to or better than flag ribbons on FSW. FSW can be used on both hard cable and compliant cable. Preliminary estimates show that material, fabrication and installation of FSW will cost less than seventy-five cents per foot. Delivery of this fairing could begin three months after the order to proceed. This was discussed with Dr. Gaul on 21 March 1974.

FSW is formed from 10 mil thick polyurethane sheet. Tests have shown that a 6 inch width is approximately optimum. A production run of 10 mil by 18 inch polyurethane sheet is then to be cut into three 6 inch widths. The 6-inch strip is then sliced normally from one edge into flags of 3/8 to 1 inch widths and about 4 inch lengths, leaving a 2 inch undisturbed header along one side of the strip. The material is glued to the cable along the surface of the header in a helical wrap.

Long life and resistance against loss of ribbons when wound on a drum under line tension of up to 1500 pounds and greater has been demonstrated on a similar application on the MABS system. No stronger material than polyurethane for this application is known.

2.4.4 RECOMMENDATIONS. MSAG recommends the following action:

a. FSW be subjected to further testing at Woods Hole both to measure its strumming attenuation effectiveness and to evaluate its endurance to a high velocity environment.

b. Subject to satisfactory results of the tests recommended in "A", FSW be procured for installation on all ACODAC cables used in future exercises unless other forms of fairing are employed.

c. Woods Hole should provide Hair-in-Braid fairing on the KEVLAR cable recommended for their acquisition in Section 2.3.5 above.

d. After the FY 75 exercise season the relative effectiveness and cost effectiveness of FSW vs KEVLAR fairing should be evaluated for purposes of future acquisition decisions.

2.5 END-TO-END CALIBRATION.

2.5.1 GENERAL CONSIDERATIONS. The purpose of the buoy systems is to place acoustic instrumentation in the deep ocean. This instrumentation is intended to measure and report absolute sound pressure level to a high accuracy. The systems are designed to accomodate flexibility in the sensor configuration through modular construction. Assembly of these modular components is accomplished on board ship or at staging areas remote from factory or laboratory facilities. Calibration and checkout procedures, which verify performance of each component, have been established and are used prior to each deployment.

2.5.2 CALIBRATION AND CHECKOUT PROBLEM AREAS. Experience has pointed up several weaknesses in the component approach to calibration and checkout. As presently known, these weaknesses are listed as follows:

a. An extremely tedious, and very often incomplete, collation of the data into a system calibration.

b. Undiscovered malfunctions and errors such as connector pin discontinuities and miswiring of couplers.

c. In situ variation and degradation of performance.

These factors lead to repetitive back tracking and qualitative interpretation of the collected data. A recommended solution is to provide an End-to-End, system level calibration or performance monitor, which is useful both in predeployment checkout and in situ.

2.5.3 RECOMMENDATIONS. Several methods of implementation have been identified and at least one method successfully used at-sea. Feasibility and usefulness have been demonstrated. Of the several alternatives available, the final choice is best to be made by the designer after careful study of the tradeoff between cost, reliability and accuracy/stability. However, MSAG makes the following recommendations:

a. That the calibration signal be inserted electronically, in order to negate the possible errors associated with acoustic insertion.

b. That, when the hydrophone/preamp construction allows, the insertion of the calibration signal be accomplished in series with the hydrophone impedance.

c. That the timing of the calibration sequence be controlled from the instrument pressure vessel so that synchronization problems do not multiply.

d. That the accuracy of the calibration tone generator be no worse than ±0.1 dB (1%) over the full temperature range of 0 to 50°C.

e. That crosstalk between channels not be degraded beyond the present 35 dB down due to capacitive coupling and 30 dB down due to common mode.

f. That at least two frequencies be considered; one at 50 Hz and the second near the low frequency roll off of the hydrophone.

g. That the stability of the calibration tone be compatible with the 0.1 Hz resolution requirement of the Analog-Digital ACODAC over the temperature range of 0 to 50°C.

2.5.4 <u>ESTIMATED COST</u>. Estimated cost is of the order of $1000 per hydrophone for delivered hardware. Development cost is estimated at $20,000 per system type. Delivery is probably constrained by component procurement so that a system fully tested on-land could be available in 6 months ARO.

2.6 ANALOG MAGNETIC TAPE AND RECORDING/REPRODUCTION.

2.6.1 PROBLEM. The LRAPP program makes use of magnetic tape in the analog mode. As data has been collected, it has become clear that there are difficulties and problems directly related to the retrieval of valid data from magnetic tape.

Due to the nature of the problem of recording data and retrieving it from magnetic tape, it is impossible to simply consider problems in relation to the magnetic tape alone or with respect to the record/reproduce magnetic heads alone. The two elements interact with each other and it is impossible to make a unilateral analysis of any failure mode in the data retrieval process without considering both the magnetic tape and the magnetic heads together.

Both the magnetic tape and the magnetic heads are vulnerable to various environmental parameters, such as temperature, relative humidity, particulate matter, and mechanical handling. Each of these parameters affect the system in different ways and each parameter may also negate the ability to retrieve valid data, or even useful data.

2.6.2 APPROACH. The following approach was used to address the problem of improving the retrieval of valid data from magnetic tape. Specific areas which affect data retrieval were determined and defined. Each of these areas was then investigated to determine the difficulties associated with retrieving valid data. Recommendations were then made to alleviate these difficulties. The areas addressed should not be considered exclusive and no attempt was made to rank the contribution of each area to solving the problem.

2.6.3 RESULTS. The following paragraphs discuss areas identified as influencing the quality of data retrieved from magnetic tape.

a. VERIFIED TAPES.

All authorities that have been contacted with respect to the problems which LRAPP faces agree that it is essential that we make every effort possible to use only verified tapes at all points in data recording and duplication. Using magnetic tape whose properties are known literally for each millimeter and for every track, we can enhance the accuracy of signal level measurements and make the in situ calibrations much more useful and accurate.

b. TAPE SELECTION.

Type 3M 801 magnetic tape has been utilized as the best known available tape at present for LRAPP data recording. It is now clear that other tapes should be carefully examined to see if they may not be superior to the 3M 801. It will also be necessary to determine the degree of uniformity of tapes obtained from a manufacturer. With suitable system control, the performance of magnetic tape is predictable. Possible candidates for utilization are Ampex "Audio Mastering Tape", Ampex type 407 and also wide band tapes presently available on the market.

c. MAGNETIC RECORD/REPRODUCE HEADS.

All available evidence points to the advisability of utilizing narrower track widths on the reproduce head than on the record heads. The figures as originally recommended, specifically 50 mils for the record track width and 45 mils for playback appear optimum. For reasons presently unknown this method is not currently being utilized generally for analog data recording. But if one is attempting to obtain data free from amplitude variation due to lateral motion of the tape, this appears to be an obvious advantage.

Other than in the very low tape speed systems, such as ACODAC, for recording purposes, it appears advisable to pursue the substitution of the relatively soft magnetic alloys with the newer hard alloys such as represented by Spin Physics heads. A major advantage of the harder alloy materials is their improved resistance to abrasion and to adverse levels of relative humidity.

Some tape recorder manufacturers are completely lacking in mechanical data with respect to heads such as the degree of torquing of the mounting screws, etc. It is essential to obtain or develop such data for use on all recorders used in LRAPP programs. Improper torquing may misalign the magnetic heads. Under no circumstances is manual torquing, without the use of torque wrenches, acceptable.

When precision is required, the practice of photographing or "fingerprinting" the magnetic heads is imperative. This should be done before installation and at any time during the use of the particular recorder if there appears to be a difficulty either with the magnetic tape or the magnetic heads. There is strong evidence that scanning electron microscopy (SEM) may be significantly better than optical photography for the fingerprinting purposes. It is also highly recommended that ultraviolet photography be employed incorporating a proper filter to record fluorescence of unwanted resins which sometimes are not completely removed from the magnetic heads. Spare magnetic heads, to facilitate field operations or tape duping should also be fingerprinted. Any heads that are considered as presenting a problem should be returned to a designated place for re-fingerprinting and examination. It is obvious that complete documentation for each head is imperative.

d. ALIGNMENT TAPES.

When magnetic tapes are recorded on one machine, and duplicated and played back on others, the magnetic head azimuths should be identical within extremely narrow limits. The problem is a very old one from the standpoint of data recording and has been adequately resolved by the establishment of standards known as "Telemetry Standards" of the IRIG (Inter-Range Instrumentation Group). As a result of much study and work on the part of various government laboratories, there are now available standard alignment tapes known as RLCO tapes (R L Electronic Communications Co., Inc., 1348 Callens Rod., Ventura CA 93003). These tapes are available from GSA stock.

The RLCO head azimuth test tape can also be used as a precision means of determining accuracy of gap alignment between tracks. This makes possible precision time determination of alignment dispersion which is essential for accuracy of acoustic phase measurements.

e. TEST TAPES.

To insure that all analyses made from tapes are comparable and to establish data accuracy and inter-comparability suitable test tapes should be made utilizing high quality verified tapes. Master tapes of this type must be prepared and tightly controlled dupes made which may be utilized as both reference and working standards for each laboratory. The master test tapes should be adequate for evaluating all of the data analyses to be performed. There appears to be no other way of insuring the validity of the analyzed data. Further, the master tapes furnish a means of comparing methods of analyzing tapes from year to year.

Each group or laboratory should have both reference and working test and alignment tape. The reference tapes should be carefully stowed and used only when there is a suspicion that something may have happened to the working tape.

f. DUPING MAGNETIC TAPES.

The duping of magnetic tape must be carried out in ultra clean environmental conditions on equipment which has been carefully checked by use alignment and test tapes, and has had electronic adjustments such as bias, etc. Personnel concerned with duping must make every effort to exercise high quality control.

Only completely verified tapes should be used in duping. These may be tapes which are of slightly less quality than prime tapes. The documentation from the verification process will establish the tapes capability and limitations.

g. MECHANICALS.

The entire magnetic tape transport mechanism must be carefully aligned and adjusted, particularly the tape tension adjustments, to avoid distortion or damage to the magnetic tape. The winding or spooling of magnetic tape should be such as to promote uniform or even packing. Uneven packing makes the tape highly vulnerable to damage along its edges. This is true even if wrap-around rings are used for the support of the reel flanges. Under no circumstances should magnetic tape be left for any significant period of time with an uneven pack as this may introduce permanent mechanical distortion in the tape. One of the reasons for "fingerprinting" magnetic heads is that a very minor mechanical imperfection on the head such as an improperly clamped lamination can easily permanently damage the magnetic tape oxide layer.

h. ENVIRONMENTAL CONSIDERATIONS.

Magnetic tape possesses relatively high sensitivity and vulnerability to many environmental parameters and should be considered to be highly fragile in view of the environmental effects which may so insidiously and disastrously degrade the accuracy of recorded data. Only by thoroughly understanding the sensitivity of magnetic tape to the environment and insuring that it obtains proper protection at all points and at all times may valid data be obtained. Magnetic tape also interacts both mechanically and chemically with tape transport mechanisms and magnetic heads and this gives rise to a special range of problems which must also be understood. The marine environment itself is most severe and has highly adverse effects on magnetic tape.

Magnetic tape record/reproduce systems may only be utilized within a relatively narrow range of temperatures. At temperatures below 3-4°C, the magnetic tape polyester base undergoes mechanical changes which tend to modify the tape contour over the magnetic gap area of the magnetic heads. At temperature above 105°F (40.5°C), the polyurethane binder of the magnetic oxide begins to soften and as temperatures increase becomes progressively more tacky. Rather serious damage to the polyurethane may be expected by 120°F (48.9°C). <u>These temperature effects are permanent and irreversible</u>. Magnetic heads undergo changes in permeability of significant value between the range of 3-4°C to 23-24°C that result in changes of optimum recording bias for the magnetic heads requiring careful checking, particularly in the case of any system recording in situ at considerable depths. Ideally, magnetic tape should not be subjected to temperature changes at all and if it is, such as in the case of ACODAC systems, it should be allowed to equilibrate, if at all possible, a minimum of 24 hours at the new temperature before using.

Relative humidity also has direct effects on the magnetic tape-magnetic head system. The optimum range of relative humidity is between approximately 20-25 percent RH on the low end and no higher than 42 percent RH on the high end. Though they are not synoymous, both friction and abrasion tend to increase at both extremes of humidity. Two effects specifically related to low relative humidity are known as gap smear and brown stain. Gap smear is caused by the magnetic tape physically transporting some of the metallic material from the upstream portion of the magnetic gap to the downstream portion and in so doing builds up a magnetic bridge changing the magnetic reluctance of the gap. The net effect is attenuation of signal frequency from the tape. The brown stain, on the other hand, is not as well understood but also results in the loss of signal level and can only be removed by utilizing special abrasive magnetic tapes. Lossess of 3-5 dB may be attributable to the gap smear and 6-10 dB may occur due to brown stain.

Particulate matter is essentially a contaminate or pollutant to magnetic tape record/reproduce systems. Many particles are highly abrasive and extremely detrimental to data retrieval from magnetic tape. Depending upon how a polluting particle behaves, there may or may not be a serious problem in the data retrieval process. A major problem with particulate matter is that much that is very seriously troublesome is actually invisible to the naked eye. The ability of particulate matter to degrade the performance of magnetic tape has been known for many years. As a specific example of the seriousness of the problem, a particle from cigarette smoke of a diameter of roughly 25 microinches causes a drop in signal level at a 300 Hz frequency at 15/160 IPS of 4.5 dB. The 4.5 dB drop would also be experienced when the 300 Hz signal is duped at 60 IPS. An example of the sizes of common materials is shown in Figure 4 where the sizes of particles are given both in microns and microinches. The dotted lines refer to the decibel loss in the magnetic record/reproduce system due to particles of the sizes shown in the graph.

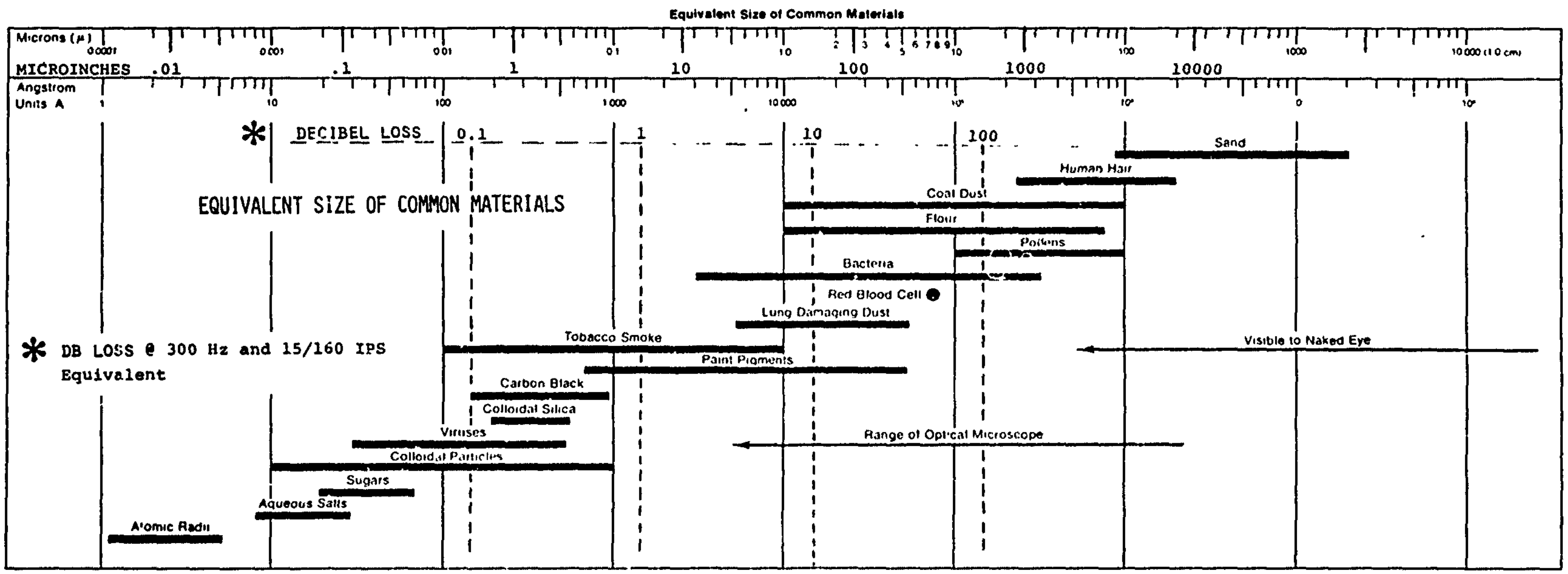

Figure 4. Equivalent Size of Common Materials

Perhaps one of the greatest risks of all to magnetic tape is posed by people: poor or careless handling of the tape or simply being the source or vehicle for bringing many particulate pollutants into contact with the tape or magnetic heads, e.g., from deodorant spray powders, face powder and human hair. Spray types of insecticides are virtual "dynamite" since they contain large quantities of diatoms.

2.6.4 RECOMMENDATIONS. Based on the previous discussion, the following conclusions are made to assure the retrieval of valid data for the LRAPP program.

a. VERIFIED TAPES.

Use only verified tapes for prime recording, duplicating, and test tapes.

b. TAPE SELECTION.

Tapes other than 3M 801 should be analyzed to see if they may not be superior.

c. MAGNETIC RECORD/REPRODUCE HEADS.

Discuss the advisability of utilizing narrower track widths on the reproduce heads with magnetic head manufacturers. Substitute soft magnetic alloys with newer hard alloys in the heads. Assure the proper torquing of the head mounting screws on all recorders. Fingerprinting of all magnetic heads should be mandatory; SEM photographs are preferred to visible light. Ultraviolet photography shall be used to detect unwanted resins. Appropriate documentation shall be maintained.

d. ALIGNMENT TAPES.

RLCO tapes be made mandatory for all LRAPP tape users. Initially, RLCO head azimuth test tape, Catalog No. A17371-10-1/2-S, should be obtained by all users. This is a 1.0 mil IB (intermediate band), 10-1/2" reel (3600' length), 1/2 inch. Other RLCO tapes may later be deemed essential, but in any case this tape should be available to all users.

e. TEST TAPES.

Prepare master test tapes to be utilized as reference and working standards for each laboratory.

f. DUPING MAGNETIC TAPES.

The duping of magnetic tapes must be done in an ultraclean environment, using only verified tapes.

g. TAPE MANAGEMENT.

Quality control in all facets of analog tape handling is of great importance. Accordingly, it is recommended that the LRAPP Office contract a function to be known as "Tape Management" to a qualified organization. The tape management function shall include the following:

a. The selection of tapes from the manufacturer;
b. The verification of tapes;
c. The development and maintenance of test tapes;
d. The duplicating of tapes; and
e. The archiving of tapes.

In addition, the tape manager should issue instructions for the handling of tapes for all phases of the data acquisition and analysis process. The overall tape management process is illustrated in Figure 5. The dotted line indicate those aspects of the process that should be under the direct supervision and control of the tape manager.

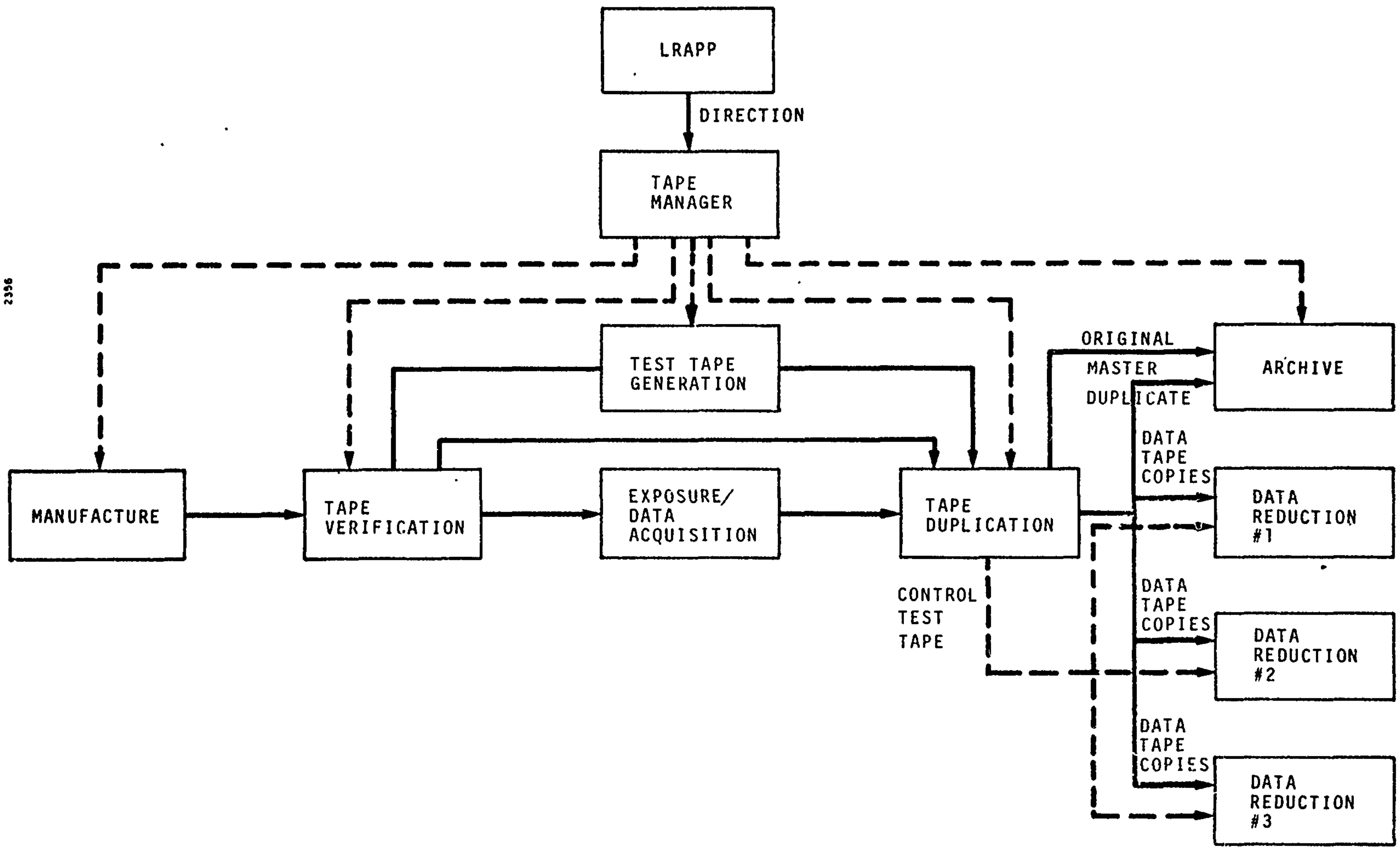

Figure 5. Tape Management Flow Diagram

2.7 HYDROPHONE CALIBRATION.

2.7.1 THE PROBLEM. Normal practice within the LRAPP program has been for each activity developing array systems to develop unique hydrophone calibration procedures. As a result, the procedures used, data obtained, and number of phones calibrated are not relatable. The purpose of this program is to standardize the calibration of hydrophones used in LRAPP-sponsored exercises. A two-phase program is proposed. Phase I would stress the hydrophones beyond the requirements of use today. Phase II would standardize the calibrations executed for pre and post exercise calibrations. Phase I provides the data base for all future calibrations and provides essential data for decision-making for present hydrophones, perhaps modified, being used within newer, more stringent measurement systems. Phase II provides inputs for statistical data regarding such parameters as hydrophone reliability, system error analysis and hydrophone stability.

2.7.2 APPROACH TO SOLUTION. The USRD, Orlando, Florida, has a store of data, knowledge and insight relative to hydrophone technology, in general, and applications similar to LRAPP requirements in particular. Association with development of particular hydrophone types, continued calibration of hydrophones in use and in-house capability for testing of a broad spectrum of hydrophone characteristics represents a base of knowledge not available elsewhere in the LRAPP community. It is anticipated that USRD will contribute comments and make recommendations relative to hydrophone suitability and/or improvement.

2.7.3 RESULTS. The following work statement has been discussed with USRD:

The calibration on each hydrophone shall be made in accordance with the following requirements:

a. The sensitivity shall be measured and reported at the following frequencies: 2, 5, 10, 20, 50, 100, 200, 1000, 2000, 3000, and 4000 Hz (every third 1/3 octave band over the range of interest). These twelve data points shall be supplied at each temperature-pressure value for each hydrophone. Any resonances should be noted.

b. The sensitivities shall be measured at the following temperature-pressure values:

		Temperature				
Depth	Pressure	4°C	9°C	14°C	19°C	24°C
1000 ft	1.3 MPa	X				
3333 ft	10.0 MPa	X	X	X	X	X
10,000 ft	13.0 MPa	X				
20,000 ft	17.0 MPa	X				

c. The following parameters shall be reported:

1. Dynamic Range.

As a minimum the saturation level of hydrophone preamp as a function of frequency shall established. At those frequencies where USRD facilities will allow, the noise floor of the hydrophone/preamp shall be determined.

2. Impulse Response.

Impulse response testing shall be performed. In particular, recovery time from overload is of interest.

3. Intermodulation Distortion.

Two tone intermodulation testing shall be performed.

In addition to documenting the hydrophone sensitivities, the successful and economical operation of the LRAPP operation is dependent upon for each hydrophone:

a. Verify that the construction techniques used in these hydrophones are suitable for LRAPP usage.
   1K to 20K feet depth - all oceans unattended
   10 to 30 day periods absolute sound pressure
   level measurement to ±0.5 dB accuracy

b. Identify any unique performance oddities (resonances, roll-offs) of these hydrophones. Determine if these performance oddities are predictable and/or controllable.

c. Determine if the effects of temperature and pressure on hydrophone performance are independent.

d. Identify any variation of hydrophone response as a function of time spent in these environments.

e. If possible, separate sensitivity variations into systematic vs random categories. Identify methods available for either prediction or on-site measurement of systematic and/or random variations.

f. Identify any fatigue factors which influence the hydrophone response after repeated use in the environmental extremes.

g. Determine if the boot will absorb water under the calibration conditions, and what effect will this have on the hydrophone response.

h. Determine if the hydrophone requires a settling-in time to adjust to the environment before stable performance is achieved. If so, quantify this time.

i. Determine the directionality of these hydrophones below 4000 Hz.

j. Identify the effects on reliability and failure rates of these environments for the hydrophones preamp.

k. On the basis of these tests determine if the hydrophones meet the applicable performance specifications.

2.7.4 RECOMMENDATION. That the LRAPP office establish and implement a uniform hydrophone calibration procedure in accordance with the above text.

2.8 ERROR ANALYSIS.

2.8.1 BACKGROUND. A worst-case analysis of the possible error in reported ACODAC results has recently been prepared by B-K Dynamics Inc. (TR-3186). This analysis attempts to identify and quantify the possible errors in each step of the process and then combines these into the final result. It is then possible to examine each of these terms and estimate the improvement which could be obtained.

2.8.2 SUMMARY OF RESULTS. The above mentioned report estimates the worst case error; the probable error is approximately one third of this figure. The results of three basic measurements are presented below.

Measurement	Worst Case(%)	Probable
Ambient Noise	23	8
SUS Transmission Loss	23	8
VIBROSEIS Trans. Loss	27	9

The following table illustrates the significance of percentage vs decibel errors.

%	dB
1	.1
2	.2
6	.5
12	1.0
19	1.5
26	2.0

2.8.3 IMPROVEMENT METHODS. Four basic areas of improvement have been identified. The first is complete end-to-end calibration, including the data processing; second, a complete hydrophone calibration to within 0.1 dB (1%) over the frequency and dynamic ranges of the systems; third, use of first tape duplications in lieu of second and use of the running calibrations on the tape; last, reduction of hydrophone cable crosstalk.

Measurement/Improvement	After Improvement Worst Case(%)	Probable(%)
Ambient		
End-to-End	17	6
Phone Cal	18	6
Tape Dup	20	7
Cross Talk	22	7
TOTAL	7	2
SUS Transmission Loss		
End-to-End	17	6
Phone Cal	18	6
Tape Dup	20	7
Cross Talk	22	7
TOTAL	7	2
VIBROSEIS Transmission Loss		
End-to-End	21	7
Phone Cal	22	7
Tape Dup	24	8
Cross Talk	26	9
TOTAL	11	4

The hydrophone calibration contributions are so large because they are entered twice in the measurement: at the listening end and at the source end.

3.0 ADMINISTRATIVE PROBLEMS AND RECOMMENDATIONS

3.1 GENERAL CONSIDERATIONS

The LRAPP office is under constant pressure to conduct acoustic are assessment exercises. Often these are large, complex undertakings involving many ships, aircraft, measurement systems and even nations. Needless to say they can be, and usually are, expensive. The very fact that these exercises are feasible in terms of the desired acoustic results is based to a large extent on the existence of unattended automatic measuring systems such as ACODAC, MABS and ANB. These systems came into being because there was a demonstrable need to improve the efficiency and effectiveness of acoustic data acquisition; the time honored methods of dangling or towing hydrophones from ships were not good enough. The point needs to be made that the present measurement systems are not yet fully developed and operating at the peak of efficiency. Many shortcomings exist; solutions to the most obvious of these have been recommended in this report. Recognizing that LRAPP's product is the generation of specific information required for the design of ASW surveillance systems and that LRAPP's performance is sometimes judged by the quantity of data recovered and reduced from which this information is derived, it is important to note that in the long run the quality of data can be even more important than quantity and that both quality and quantity can be significantly improved through continued development of measurement systems. It seems reasonable then that some fraction of the LRAPP budget be allocated towards system improvement. The balance between the fraction of effort devoted to using systems versus that devoted to improving systems is a matter of judgement which will vary with circumstance. The point made here is that all of the effort should not go to exercises and modeling; some identifiable fraction should be allocated to system improvement.

3.2 RECOMMENDATIONS

MSAG submits the following general administrative recommendations:

a. Up to ten percent of the LRAPP budget should be set aside each year for development of new measurement systems and improvement of existing measurement systems. Measurement systems are used here includes the entire complex by which signals are generated, measured and analyzed; it includes sources, receivers, data processing methods and hardware.

b. LRAPP should concentrate its development funds in systems over which LRAPP exercises complete control. In this way the maximum benefit to cost ratio is anticipated. In special circumstances certain specific development items for systems not under LRAPP control might be considered on a case by case basis, but the bulk of support should go to those systems under LRAPP jurisdiction.

3.3 PRIORITIES OF THESE RECOMMENDATIONS

Each of these recommendations was chosen for presentation because MSAG believed it to be important. A listing by priority does not imply that the one at the bottom is unimportant; rather it means that in event that choice is necessary due to budget constraints, those higher on the list should receive first consideration. Two lists are presented below, one list includes the short term improvements to present systems; the second (with only one item) concerns mid term major alterations to the ACODAC system. MSAG recommends the following priorities for the technical recommendations made in the paragraphs above.

A. Improvements to Present Measurement Systems

Priority Numbers	
1	Strumming Counter Measure (See Paragraph 2.4)
2	Error Analysis (See Paragraph 2.8)
3	End-to-End Calibration (See Paragraph 2.5)
4	Analog Magnetic Tape Management (See Paragraph 2.6)
5	Uniform Hydrophone Calibration (See Paragraph 2.7)
6	Miscellaneous Measures Relating to Cables and Connectors (See Paragraph 2.3)

B. Major Alterations to Present Measurement Systems

7	In Situ Analog/Digital Data Acquisition System (See Paragraph 2.2)

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University of Hawaii at Manoa
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Attn: Dr. Richard L. Laugfield (1)

Hawaii Institute of Geophysics
University of Hawaii at Manoa
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10 Rickenbacker Causeway
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Attn: Dr. E. E. Hays (1)

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OFFICE OF NAVAL RESEARCH
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1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
WHOI73-59	Tollios, C. D.	THE ACODAC DATA PROCESSING SYSTEM	Woods Hole Oceanographic Institution	730901	AD0773114; ND	U
Unavailable	Russell, J. J.	DOCUMENTATION FOR COMPUTER PROGRAM SUMMARY: A COMPUTER PROGRAM TO SUMMARIZE SOUND SPEED PROFILE DATA	Naval Undersea Center	731001	AD0918907	U
MC001Vol2	Unavailable	CHURCH ANCHOR DATA ANALYSIS PLAN VOL 2 (U)	Maury Center for Ocean Science	731001	ND	U
73-9M7-VERAY-R2	Jones, C. H.	LRAPP VERTICAL ARRAY- PHASE III	Westinghouse Research Laboratories	731105	ADA001130; ND	U
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT	Underwater Systems, Inc.	731201	ND AD 785875	U
ARL-TM-73-42	Mitchell, S. K., et al.	QUALITY CONTROL ANALYSIS OF SUS PROCESSING FROM ACODAC DATA	University of Texas, Applied Research Laboratories	731220	ND ADB 000 283	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: CONTINUOUS CURRENT PROFILES	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740101	AD0775333	U
Unavailable	Bitterman, D. S.	ACODAC AMBIENT NOISE SYSTEM	Woods Hole Oceanographic Institution	740101	ADA009440	U
ONR MC-002 VOL. 2; XONICS 885	Unavailable	LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP). SQUARE DEAL DATA ANALYSIS PLAN (U) VOLUME 2 - ANNEXES	Maury Center for Ocean Science; Xonics, Inc.	740101	ND	U
ARL-TM-74-12	Groman, R. O., et al.	SPECIAL HARDWARE FOR ARL ANALYSIS OF ACODAC DATA	University of Texas, Applied Research Laboratories	740314	ADA000295; ND	U
Unavailable	Unavailable	ASEPS NEAR FIELD TRANSMISSION LOSS MODIFICATION, P-2205	Ocean Data Systems, Inc.	740401	ADA096583	U
Report 001; MSAG-1	Unavailable	MEASUREMENT SYSTEMS ADVISORY GROUP	Office of Naval Research	740401	ADA096586; ND	U
ACR-196	Gregory, J. B.	PROJECT PACIFIC SEA SPIDER, TECHNOLOGY USED IN DEVELOPING A DEEP-OCEAN ULTRASTABLE PLATFORM	Office of Naval Research	740412	AD0529945; ND	U
Unavailable	Gottwald, J. T.	ANNUAL REPORT FOR 1 MAY 1973 - 30 APRIL 1974	Tracor, Inc.	740524	AD0920210	U
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HCI-CMC-18540	Daubin, S. C.	TRANSMISSION LOSS OF LOW FREQUENCY UNDERWATER SOUND IN THE CAYMAN TROUGH (CHURCH GABBRO TECHNICAL NOTE)	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740601	ADC000424; ND	U
HCI-CMC-18343	Daubin, S. C.	AMBIENT NOISE IN THE NORTHWEST CARIBBEAN SEA (CHURCH GABBRO TECHNICAL NOTE) (U)	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740601	ND	U
Unavailable	Barnes, A., et al.	DISCRETE SHIPPING MODEL	Planning Systems, Inc.	740604	ND	U